Pax islamita (Araneae: Zodariidae) as a new host of an acrocerid fly from Israel

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Abstract. Records of interactions between acrocerid parasitoids (Diptera: Acroceridae) and their hosts are very scarce. Here we report a case of acrocerid fly (most likely *Ogcodes* sp.) parasitising zodariid spiders of the genus *Pax* from Israel. We describe the parasitoid development and possible host manipulation.

Keywords: ant spider, host manipulation, host-parasitoid interaction, ontogenetic development

Zusammenfassung. *Pax islamita* (Araneae: Zodariidae) als neuer Wirt einer Kugelfliege (Acroceridae) aus Israel. Nachweise von Interaktionen zwischen parasitoiden Kugelfliegen (Acroceridae, auch Spinnenfliegen genannt) und ihren Wirten sind sehr selten. Wir berichten von einer Kugelfliege (wahrscheinlich *Ogcodes* sp.) die eine Zodariide (Ameisenjäger) der Gattung *Pax* in Israel parasitiert. Die Entwicklung des Parasitoids und eine mögliche Manipulation des Wirtes werden beschrieben.

Spiders are a frequent prey of many vertebrate and invertebrate predators (e.g., Foelix 2011). They also fall prey to a number of hymenopteran and dipteran parasitoids which are often specialised on a certain foraging guild (e.g., Gauld & Dubois 2006, Korenko et al. 2014). While the former are often ectoparasitoids, the latter are mainly endoparasitoids, therefore very difficult to record. Among flies (Diptera), several families species that are known to exploit spiders, but the most important are acrocerids (Gillung & Borkent 2017).

Acrocerids (Acroceridae) are specialised internal parasitoids of spiders, mostly of cursorial species (Schlinger 1987). They are highly diversified, and therefore are specialised on certain prey guilds (Gillung & Borkent 2017), yet some species showed a higher trophic specificity (Cady et al. 1993). The biology of Acroceridae remains poorly known due to limited records, however, the overall course of life is known. The female disperses eggs on the vegetation. The hatched larvae then seek hosts and at the second instar inject themselves through the cuticle into a host (Nielsen et al. 1999). The remaining larval development occurs in the host body. The larva emerges from the host via the opisthosoma after some time and creates a puparium outside the host. The imago hatches within a few days (Cady et al. 1993).

Records of acrocerids come from 34 spider families, both from Mygalomorphae and Araneomorphae, and almost all spider clades (Gillung & Borkent 2017), but not from Zodariidae. In Israel zodariid spiders are locally abundant cursorial spiders (Pekár & Lubin 2003). There are 19 species belonging to six genera reported from Israel so far (World Spider Catalog 2019). Zodariid spiders have been rarely reported as hosts of parasitoids worldwide. Korenko et al. (2013) recently discovered two species of ichneumonid wasps' ecto-parasitising juveniles of *Zodarion styliferum* (Simon, 1870). Furthermore, *Z. cyrenaicum* Denis, 1935 was found to be ecto-parasitised by an ichneumonid wasp larva (Pekár et al. 2005). *Lachesana* sp. was observed to be hunted by a *Pedinpompilus* sp. wasp (Pekár unpublished); and *Lutica* has been reported to be parasited by a therevid fly (Ramirez 1995).

Here we report the first case of an acrocerid fly parasitoid that emerged from *Pax* spiders. We provide a description of the hatching from the host and possible host manipulation.

Material and methods

Pax islamita (Simon, 1873) spiders are medium sized (6–10 mm in adult stage), inhabiting leaf litter (Levy 1990). They were collected by hand under stones near the Adulam Nature Reserve (31.63419°N, 34.94669°E, 385 m a.s.l.), in central Israel, on 4. Apr. 2017. Specimens (n = 18, all juveniles) were placed individually into glass tubes (diameter 15 mm, 60 mm long) with a layer of gypsum on the bottom covered with a layer of sand. Spiders were kept at a room temperature of 24 °C and natural LD = 14:10 regime. One moth prey individual, *Ephestia kuehniella* Zeller, 1879, was offered to each spiders the next day.

Results

Out of 18 individuals collected, two juveniles constructed igloo-shaped retreats using sand grains within 24 hours after placing them onto sand (Fig. 1a). The other individuals constructed a retreat only 12 days after consuming prey, within which they moulted. These first two spiders did not accept prey (*Ephestia* moths), while all others (i.e. the non-parasitised spiders) did.

Two weeks later the first fly larva emerged from one individual via a dorsal opening on the opisthosoma (Fig. 1b). The larva produced a few strands of silk by which it was attached to the side of the retreat. The other larva (Fig. 1c) emerged three days later. Only the first larva managed to pupate nine days after emerging from the spider host (Fig. 1d). The other larva died six days after emergence as it did not manage to get rid of its own excrement. After seven days an adult male hatched and was killed and preserved (Fig. 1e, f). The parasitoid most likely belongs to the genus *Ogcodes* Latreille, 1796 (unfortunately, the material was lost when being sent to the specialist).

Discussion

The most interesting observation was the potential manipulation of the host behaviour. The parasitised individuals built a moulting retreat which was similar in construction to the retreats of non-parasitised individuals. However, the timing of building occurred much earlier than in the unparasitised

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Fig. 1: a. retreat built by an infected *Pax* individual; **b.** carcass of *Pax*. Notice the dorsal opening on opisthosoma used by larva of *Ogcodes* for emergence (arrow); **c.** larva, after emergence; **d.** puparium; **e.** adult male, dorsal side; **f.** adult male, lateral side. Scale = 5 mm

individuals. So it seems that the fly larva triggered the spider to moult. Then the larva emerged inside the retreat, so it was used to shelter the larva and later the pupa during development. Additional observations are needed to support the occurrence of manipulation.

Hymenopteran parasitoids often modify the behaviour of their spider hosts (e.g., Korenko et al. 2014, 2018). This occurs in many different forms (Thomas et al. 2005), but most frequently it includes construction of a retreat. In spiders infected by acrocerid larvae the observed changes have not been so prominent. For example, infected spiders ingested more food (and increased biomass) than uninfected ones but their growth rate was similar (Toft et al. 2012). The only obvious behavioural change was an induction of a premoulting behaviour prior to immediate emergence of the larva. This included construction of a dense silk cell (Cady et al. 1993).

The very low prevalence of parasitoids in zodariid spiders can be explained by their natural history. Zodariid spiders often hide in underground burrows or aboveground shelters, which most likely evolved as a form of primary defence against many enemies (Jocqué 1991). Furthermore, their nocturnal circadian activity provides additional protection from day-active predators, such as wasps. For example, Ramirez (1995) found a single case of parasitised *Lutica* spider out of a thousand individuals. Other records of zodariid parasitoids (see above) are also very rare.

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